The Impact of Car Parking on Traffic Volume and Composition in Urban Conditions

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Abstract: How does parking availability shape traffic on the streets around it? This paper takes up that question for Uzbekistan, tracking the country's rising motorization rate over recent years and then zooming into a case study of parking areas in Jizzakh. We looked at traffic density, the mix of vehicles using these areas - passenger cars, freight, and public transport - and how parking facilities feed back into road traffic more broadly. After surveying capacity levels across parking areas on several urban streets and running a statistical analysis, we picked one specific site, the parking area on Temiryulchilar Street, for closer study: field measurements at 50 and 100 meters from its entrance and exit let us determine instantaneous, modal, and operating speeds for vehicles on the adjacent street. At 100 meters before the parking area, the average modal speed came out to 30-35 km/h, dropping to 15-20 km/h at the exit; operating speed was 40 km/h at the entrance and 25 km/h at the exit. We also tracked the types and models of vehicles using the lot throughout the day and used that to propose design vehicle parameters, then redesigned the parking dimensions in AutoTURN - a change that increased the lot's capacity and, with it, its economic efficiency. The paper closes with a set of practical recommendations for managing vehicle parking more effectively in urban conditions, aimed at improving both traffic volume and composition.

1 INTRODUCTION

Traffic congestion remains one of the most pressing issues in metropolitan areas worldwide, contributing significantly to time loss, economic costs, and environmental degradation. One of the most pressing issues arising from these trends is parking, which requires immediate and effective solutions. The demand for parking spaces in central and peripheral areas varies widely on a daily basis, making vehicle movement a time-consuming process that negatively affects traffic flow and the quality of the environment [1].

Traffic congestion is actually a crucial issue with significantly negative effects worldwide. The outcomes are extensive, such as greater crash rates, extreme air pollution, extra fuel usage, increased travel times, as well as damage of societal wellness [2].

Vehicle speeds and accident rates both respond to shifts in traffic volume and composition, and urban street lanes see plenty of both - frequent swings in how much traffic there is and what it's made of. As people move around cities more than ever, traffic flow has climbed accordingly [3]. At present, a steady increase in the level of motorization can be observed worldwide. According to data from the State Statistics Committee of the Republic of Uzbekistan, the growth of Uzbekistan's motorization level over the years can be seen in the data presented in Table 1.

Of course, this trend can be observed not only in a single country but across the world. This, in turn, leads to an increased demand for parking spaces, which has become a serious problem today. As a result, vehicle stopping areas are increasingly forming on the carriageway itself.

The efficiency of an urban transport system depends on many factors, one of the most important being the process of vehicle parking. Irregular parking of vehicles on urban streets has a direct impact on traffic flow: traffic intensity decreases, and the uneven distribution of traffic composition disrupts flow dynamics.

Table 1: Changes in the level of motorization of the population of Uzbekistan.

Indicator	2022	2023	2024	2025
Motorization level (cars per 1000 people)	95	98	102	124
Cars per 100 households	55	57	58	59*

*Data for 2025 represent January-June.

In addition, it leads to an increase in toxic emissions from vehicles, which in turn has a serious negative impact on the environment and ecology. That makes vehicle parking, in an urban setting, more than a question of where to put cars - it functions as a transport-management lever that keeps traffic stable. Left unmanaged, it drags on vehicle movement generally: public transport operations get more complicated, road capacity shrinks, congestion builds, and speeds fall.

The contradiction between the increasing of vehicle ownership and the limitation of parking areas in city has become more serious [4]. Research indicates that the average volume of traffic related to parking during peak time can reach 30% - 50% of total traffic [5]. Scarce parking resources inevitably result in higher congestion rates and parking costs [6], [7].

Where conventional parking studies tend to stop at traffic observation, this work adds a reproducible digital workflow that ties together traffic speed analysis, statistical processing, and simulation-based parking redesign. Concretely, that means pairing real traffic data collection with algorithmic processing and AutoTURN-based geometric optimization, so that urban parking planning decisions can rest on something more concrete than observation alone.

The main contribution of this work is the development of an applied IT-driven methodology that transforms observational traffic data into digital design recommendations for improving parking efficiency and traffic flow stability in urban conditions.

2 METHODS

2.1 Study Area and Field Data Collection

There are two types of parking spaces: those reserved for specific individuals and free parking spaces available to everyone [8].

Parking capacity under urban conditions was investigated across five streets in Jizzakh - Islom Karimov, Sharof Rashidov, Alisher Navoi, Temiryulchilar, and Shifokorlar - examining the parking areas in front of organizations, institutions, enterprises, and other facilities along each. Figure 1 maps out where these parking areas sit across the city.

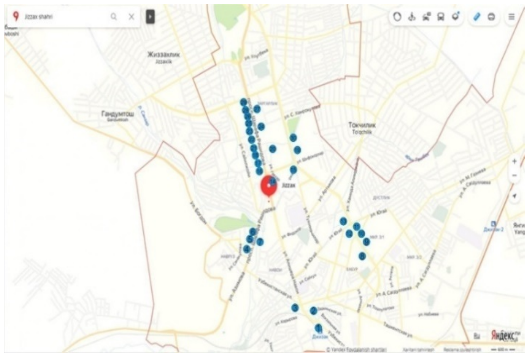

Figure 1: Spatial distribution of observed parking areas in Jizzakh city. Blue markers indicate parking locations used for field observations.

The conducted research was mainly carried out on the principal streets of the city of Jizzakh. Studies on Islom Karimov, Sharof Rashidov, Alisher Navoi, Temiryulchilar, and Shifokorlar streets in Jizzakh show that, in terms of the number of parking areas, Sharof Rashidov Street accounts for 54%, Islom Karimov Street accounts for 30%, while Alisher Navoi Street and Shifokorlar Street each account for 3% (Fig. 2).

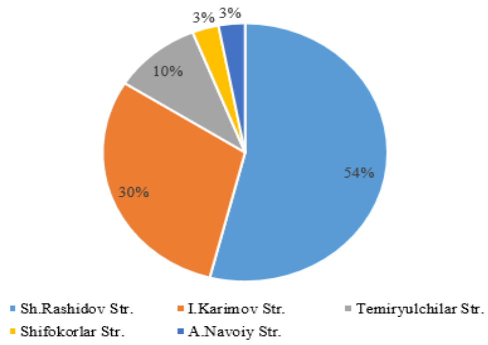

Figure 2: Distribution of parking areas across major streets in Jizzakh (percentage share).

For a closer look at how car parking affects traffic volume and composition, we settled on one site: the parking area in front of the Central Dehqon Market on Temiryulchilar Street.

Roadway condition and traffic intensity aren't the whole picture, though - vehicle speed across road lanes is a separate indicator worth studying in its own right, and it starts with measuring instantaneous speed. From there, the raw speed data goes through standard statistical methods to build distribution curves and cumulative curves: the distribution curve yields the modal speed, and the cumulative curve gives the 95th-percentile speed.

Vehicle speed was measured using a time-distance observation method. Observations were performed at distances of 50 m and 100 m from parking entry and exit locations. Each experiment included 120 vehicle observations. Speed values were grouped into intervals of 5 km/h. Distribution curves were created using frequency analysis, while cumulative curves were constructed to determine percentile speeds. Modal speed (V_mode) was defined as the interval with maximum frequency, whereas V95 was extracted from cumulative curves. The estimated measurement uncertainty due to manual observation was ±2 km/h.

2.2 Digital Solution Architecture

To satisfy the requirements of applied innovations in IT, a digital workflow was developed for analysing parking impact on traffic flow. The proposed system consists of four interconnected layers (Fig. 3):

1) Data Acquisition Layer. At each measurement point, the dataset recorded vehicle speed, vehicle category, and traffic intensity, with 120 vehicle observations per point. Fixed 50 m and 100 m reference locations defined the time–distance baselines; synchronized video frames and a digital stopwatch were used to cross-check travel time at 0.1 s resolution.
2) Data Processing Layer. Speeds were converted to 5 km/h classes, class frequencies and cumulative shares were calculated, and V_mode and V95 were derived from the resulting distributions.
3) Digital Design Layer. The locally observed vehicle dimensions were used to define the design vehicle. Candidate 90°, 60°, 45°, and parallel parking layouts were evaluated in AutoTURN by comparing swept paths, turning geometry, maneuver clearance, and usable capacity. Iterative adjustment ended when a further geometric change no longer improved clearance or reduced trajectory conflict.
4) Decision Support Layer. The final stage compared parking capacity, speed-related indicators, and maneuver-delay results and selected the configuration that provided the strongest combined operational and geometric outcome.

This architecture transforms empirical measurements into reproducible digital design decisions.

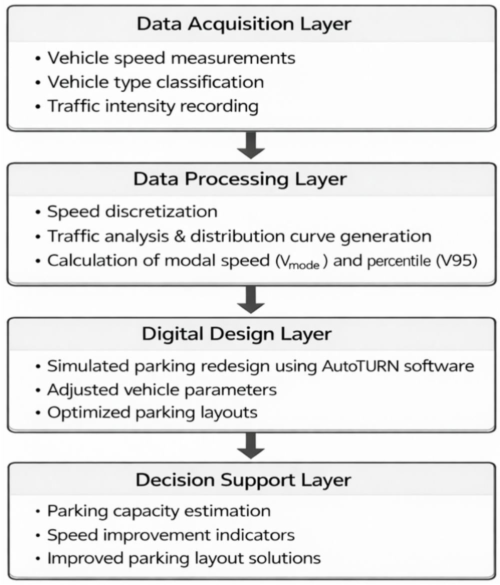

Figure 3: Transforming empirical measurements into reproducible digital design decisions.

3 RESEARCH RESULTS

The first set of measurements was taken 50 meters from the entry and exit points of the Central Dehqon Market parking area on Temiryulchilar Street (Table 2).

Figure 4 presents the distribution curve graph of the research results obtained at a distance of 50 meters from the entry and exit points of the parking area in front of the Central Dehqon Market on Temiryulchilar Street in the city of Jizzakh. According to the results, the modal speed at the parking entry is 25-30 km/h, while the modal speed at the parking exit is 15-20 km/h

Table 2: Calculation of observation tasks using statistical methods.

Speed range, (km/h)	Number of vehicles		Frequency (%)		Cumulative frequency (%)	
	Entry	Exit	Entry	Exit	Entry	Exit
15-20	1	72	0.8	60	0.8	60
20-25	19	37	15.8	30.8	16.7	90.8
25-30	76	11	63.3	9.2	80	100
30-35	21	0	17.5	0	97.5	100
35-40	2	0	1.7	0	99.2	100
40-45	1	0	0.8	0	100	100
45-50	0	0	0	0	100	100
Total:	120	120	100	100		

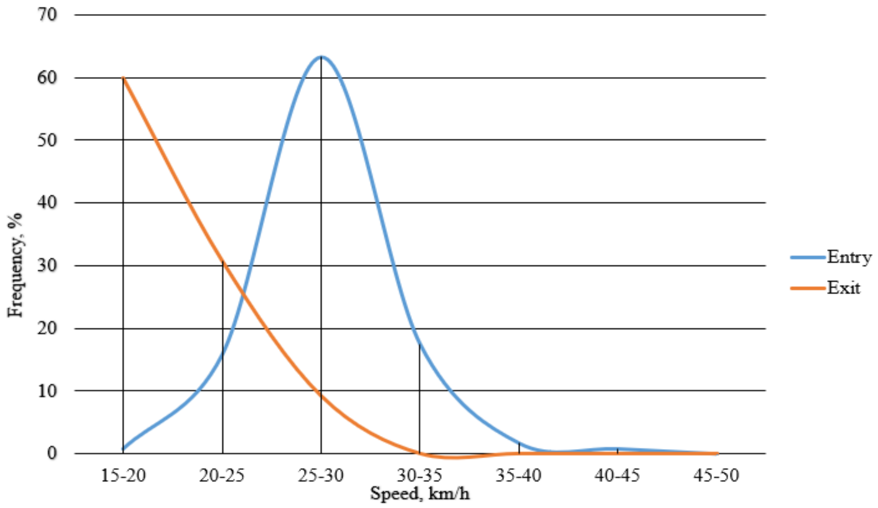

Figure 4: Speed distribution curves at 50 m from parking entry and exit points.

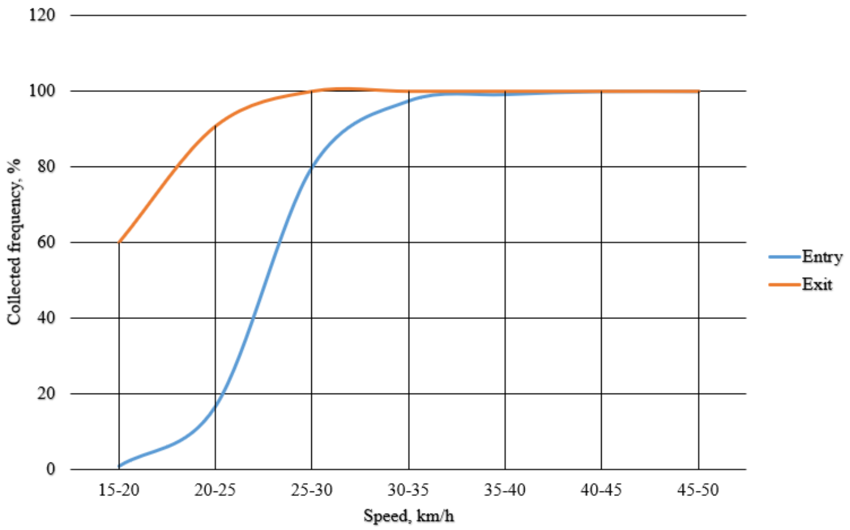

Figure 5: Cumulative speed distribution used to determine V95 design speed at the parking entry and exit.

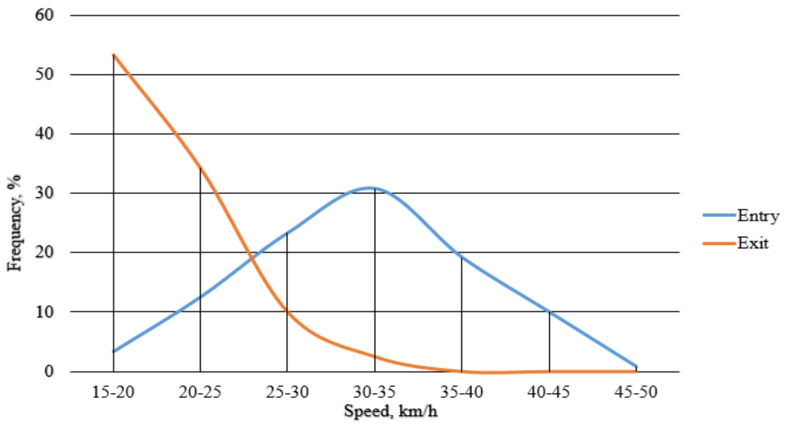

Figure 6: Speed distribution curves at 100 m from parking entry and exit points.

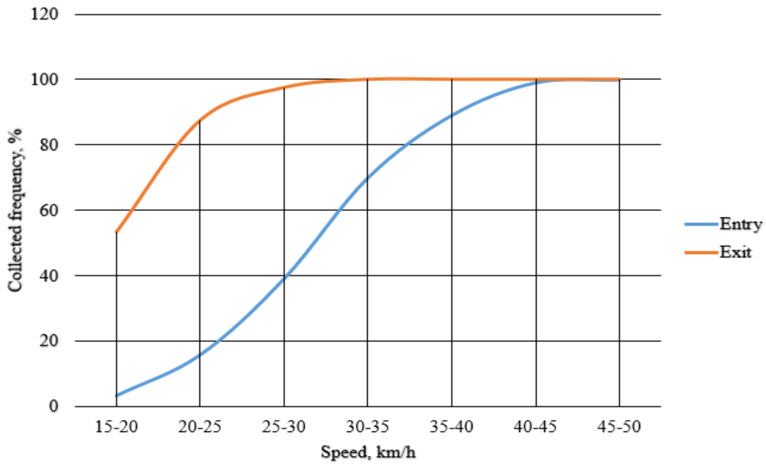

Figure 7: Cumulative speed distribution used to determine V95 design speed at the parking entry and exit.

The cumulative curve for this same 50-meter measurement is shown in Figure 5. Following standard practice, the 95th-percentile speed is taken as the design speed for calculating road elements - here, V95 = 31 km/h at the parking entry and V95 = 24 km/h at the exit.

A second set of measurements, this time at 100 meters from the same entry and exit points, followed the same procedure (Table 3).

Table 3: Calculation of observation tasks using statistical methods at the 100-meter measurement point.

Speed range, (km/h)	Number of vehicles		Frequency (%)		Cumulative frequency (%)	
	Entry	Exit	Entry	Exit	Entry	Exit
15-20	4	64	3.3	53.3	3.3	53.3
20-25	15	41	12.5	34.2	15.8	87.5
25-30	28	12	23.3	10	39.1	97.5
30-35	37	3	30.8	2.5	70.0	100
35-40	23	0	19.2	0	89.1	100
40-45	12	0	10	0	99.1	100
45-50	1	0	0.8	0	100	100
Total:	120	120	100	100		

Figure 6 presents the distribution curve graph obtained at a distance of 100 meters from the parking entry and exit points. According to the results, the modal speed at the parking entry is 30-35 km/h, while the modal speed at the parking exit is 15-20 km/h.

Figure 7 presents the cumulative curve graph obtained at a distance of 100 meters from the parking entry and exit points. According to the results, the speed at the 95 percentile is accepted as the design speed and is used in the calculation of road elements. The percentile speed at the parking entry is V95 = 40 km/h, while the percentile speed at the parking exit is V95 = 25 km/h.

Distribution and cumulative speed curves were generated using spreadsheet-based statistical processing (Microsoft Excel). Speed frequencies were grouped into 5 km/h intervals, after which cumulative percentages were calculated. The modal speed (V_mode) was determined as the class with the maximum frequency, while V95 was obtained from the cumulative distribution curve using linear interpolation between adjacent speed intervals.

The results of observations conducted to determine vehicle speed largely depend on the number of measurements taken. The reliability of the indicators is dependent on the number of measurements, which in turn depends on variations in traffic volume.

Nowadays, in all cities there is an acute problem of lack of parking spaces [10], [11]. Parking is an important component of urban transportation systems.

To recommend design vehicle parameters for vehicle parking under urban conditions, research was conducted in the parking area located in front of the Central Dehqon Market. The study found that passenger cars roughly 4.4-4.5 meters long were the most common vehicles using this lot throughout the day, which is why that size was adopted as the design vehicle parameter. These recommended design vehicle parameters are used in the planning and design of parking dimensions (Fig. 8).

National or local standards typically govern parking space dimensions, and for good reason: regulations need to match the vehicle types and models actually in use, with their particular sizes and turning characteristics. Where a country has no such standards of its own, designers often fall back on foreign ones - a workaround that can backfire if the resulting parking spaces end up poorly sized for local vehicles.

Until 1991, the design of transport infrastructure was carried out based on regulatory documents developed in the former Soviet Union. After Uzbekistan gained political independence, these standards were revised.

According to the results of field observations, the parking spaces in front of the Central Dehqon Market were designed based on outdated standards. Due to the insufficient quality of pavement markings, vehicles were parked improperly. Since the capacity of this parking area is inadequate, vehicles are often forced to park along the edge of the roadway. This leads to a reduction in road capacity, the formation of traffic congestion, and an increase in harmful emissions released into the environment.

One of the biggest challenges for drivers today is entering and exiting parking spaces.

A vehicle must be positioned in a parking spot in such a way that it is quick and convenient without causing damage to other vehicles, meaning it should be maneuvered backward into place.

Parking along the edge of the roadway is carried out in three ways:
1) parallel to the roadway;
2) perpendicular to the roadway;
3) at an angle to the roadway.

The use of specialized software systems to simulate this sequence of actions is becoming an integral part of modern design solutions. Advanced software systems are the optimal solution for designing road elements to determine the dynamic dimensions of vehicles.

The AutoTURN software tool can be used for simulating vehicle movements, designing road elements, and planning parking spaces. It is utilized to simulate vehicles of various sizes and their primary functional characteristics.

The following functions can be performed in AutoTURN:
1) modeling vehicle movement and maneuvering at speeds ranging from 1 to 60 km/h;
2) three-dimensional movement in 3D space;
3) localizing calculated vehicle parameters to match specific vehicles;
4) graphically displaying dynamic dimensions, including trajectories of outer wheels, inner wheels, overhangs, and front wheels;
5) generating angular trajectories;
6) designing parking area dimensions;
7) creating templates.

With those design vehicle parameters established, the next step was proposing parking area dimensions in AutoTURN. The recommended parameters and minimum turning radius went into the software to build a corresponding vehicle model, which was then run through simulations testing parking layouts at 90°, 60°, and 45° angles, plus parallel parking.

Simulations were conducted using the AutoTURN software to enable the recommended vehicle to enter and exit parking spaces positioned at various angles without difficulty. Based on the results of the experimental tests, the dimensions of the parking area were developed for recommendation, as shown in Table 4 (Fig. 9).

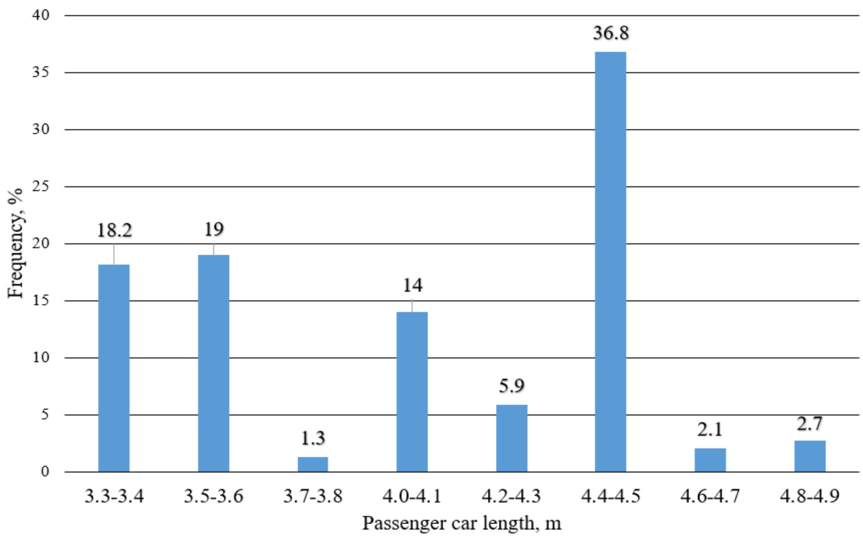

Figure 8: Frequency distribution of passenger car lengths used to define the recommended design vehicle.

Table 4: Dimensions and average areas of a single parking space.

Param.	One-way parking			Two-way parking		
	90°	60°	45°	90°	60°	45°
a, m	5.0	5.2	4.7	5.0	5.2	4.7
b, m	4.1	3.4	2.9	4.1	3.4	2.9
c, m	14.1	13.8	12.3	14.1	13.8	12.3
d, m	8.6	8.1	7.1	8.6	8.1	7.1
e, m	0.5	0.5	0.5	0.5	0.5	0.5
f, m	3.1	2.4	1.9	3.1	2.4	1.9
g, m	2.5	2.5	2.5	2.5	2.5	2.5
h, m	2.5	2.9	3.5	2.5	2.9	3.5
i, m	0.5	0.5	0.5	0.5	0.5	0.5
Area, m² (no maneuvering)	12.5	15.1	16.7	12.5	15.1	16.7
Area, m² (with maneuvering)	31.8	30.2	28.1	25.3	25.1	25.6

Note: a - depth of the parking bay; b - width of the drive aisle between rows of parking bays; c - area occupied by the parking lane and drive aisle; d - area occupied by the parking lane and drive aisle; e - safety zone; f - maneuvering zone; g - width of the parking bay; h - width of the parking module; i - length of the marking line 1.1.

Table 4 defines the geometric parameters a through i used here.

Built to outdated regulatory standards, the Central Dehqon Market parking area originally held 185 spaces. Running the Table 4 dimensions through AutoTURN pushed that up to 216 - an optimization of the technical parameters governing parking spaces and maneuvering aisles that translates directly into economic efficiency.

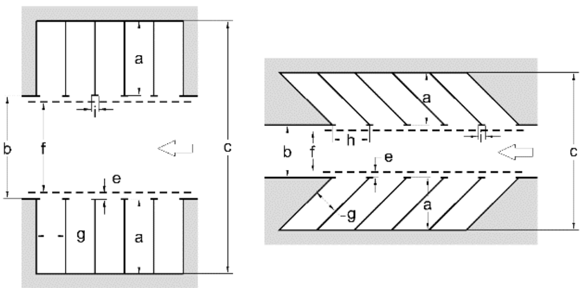

Figure 9: AutoTURN-generated parking layout schemes.

Validation results show that after applying the digital redesign workflow, parking capacity increased by 16.7%, and vehicle movement became smoother near the parking entrance. The baseline condition corresponds to the existing parking layout observed during field measurements, whereas the redesigned scenario represents the optimized configuration obtained through the proposed digital workflow under identical traffic demand conditions.

Table 5 summarizes the quantitative comparison between the baseline and redesigned parking configurations.

Table 5: Validation results of digital redesign.

Indicator	Before redesign	After redesign
Parking capacity	185	216
Modal speed entry	25-30 km/h	30-35 km/h
Modal speed exit	15-20 km/h	20-25 km/h
Maneuver conflicts	High	Reduced

Additionally, average entry and exit maneuver delay was evaluated as a validation indicator. Before redesign, the average entry delay was approximately 6.8 s per vehicle and exit delay was 7.3 s. After applying the optimized parking layout, these values decreased to 4.9 s and 5.1 s respectively, confirming improved maneuver efficiency and reduced traffic interference.

Figure 10 below presents the recommended car parameters (length, width, minimum turning radius) in the AutoTURN software, along with the radius dimensions for positioning at the specified angle.

4 DISCUSSION

Parking zones clearly shape vehicle speeds, and the effect is sharpest near exit points, where merging maneuvers pull modal speed down. That pattern echoes prior studies, though most of that work - including predictive approaches to parking demand [9] - stops short of the geometric redesign step this workflow adds: pairing digital simulation with optimization to actually reshape parking geometry, not just describe its effects. Doing so produced measurable gains in both capacity and traffic stability.

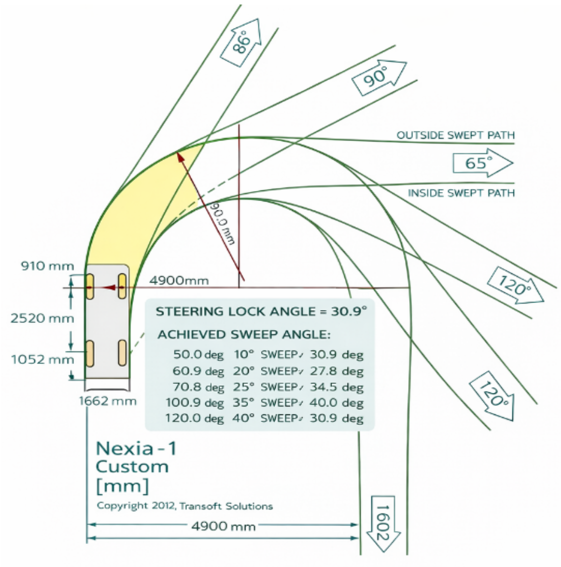

Figure 10: Recommended design vehicle parameters and turning radius simulation generated using AutoTURN.

This study proposed a reproducible digital workflow integrating traffic observation, statistical processing, and AutoTURN-based simulation for parking redesign. The results confirm that digital redesign improves parking capacity and stabilizes traffic flow parameters. The proposed approach may serve as a practical applied IT tool for urban transport planning and smart parking development.

5 CONCLUSIONS

What this work contributes goes beyond vehicle analysis alone - it's a reproducible digital workflow spanning traffic observation, statistical processing, and digital parking redesign. Urban vehicle parking shapes traffic volume and composition both directly and indirectly, and when it's done poorly, the transport system pays for it: efficiency drops, congestion builds, harmful emissions rise, and traffic safety suffers. When planning parking areas, traffic composition, flow dynamics, and urban infrastructure should be considered in an integrated manner. Based on the results of the research conducted in the parking area located in front of the Central Dehqon Market on Temiryo'lchilar Street in Jizzakh city, the following conclusions and recommendations can be made:

1) a critical speed limit should be established on the above-mentioned street, particularly on streets where market areas are located;
2) temporary stopping of vehicles along the edge of the roadway should be prohibited on two-lane streets with high traffic intensity;
3) based on the findings, the capacity of existing parking areas on this street is insufficient; in particular, a large-capacity multi-level parking facility should be constructed near the Central Dehqon Market;
4) smart parking systems should be effectively implemented on the central streets of the city;
5) artificial intelligence-based traffic management systems should be introduced;
6) priority should be given to public transport and bicycle lanes;
7) design vehicle parameters should be recommended and applied in urban parking planning;
8) parking dimensions designed using the AutoTURN software should be implemented.

REFERENCES

[1] C. Georgopoulou and P. Papantoniou, “A Literature Review of Automated Roadside Parking Monitoring Using Artificial Intelligence Algorithms,” Electronics, vol. 14, no. 20, art. no. 4119, Oct. 2025, [Online]. Available: https://doi.org/10.3390/electronics14204119.

[2] M. A. Sahraei, “Design and Implementation of a Smart Parking System with Real-Time Slot Detection and Automated Gate Access,” Technologies, vol. 13, no. 11, art. no. 503, Nov. 2025, [Online]. Available: https://doi.org/10.3390/technologies13110503.

[3] F. R. Faye, A. M. Kelecha, A. Rakhmatov, S. Mannobboyev, and J. Abdunazarov, “The impacts of improper curbside parking on traffic flow in semi-urban area, Ethiopia,” E3S Web Conf., vol. 434, art. no. 02001, Jan. 2023, [Online]. Available: https://doi.org/10.1051/e3sconf/202343402001.

[4] Q. Hu, J. Ma, G. Zhan, and F. Gao, “A dual-dimensionality reduction strategy for optimization-based parallel parking path planner,” Expert Syst. Appl., vol. 263, art. no. 125781, Nov. 2024, [Online]. Available: https://doi.org/10.1016/j.eswa.2024.125781.

[5] J. Parmar, P. Das, and S. M. Dave, “Study on demand and characteristics of parking system in urban areas: A review,” J. Traffic Transp. Eng. (Engl. Ed.), vol. 7, no. 1, pp. 111-124, Feb. 2020, [Online]. Available: https://doi.org/10.1016/j.jtte.2019.09.003.

[6] N. Ma, A. Tang, J. Hai, and F. Yuan, “Simulation model and performance evaluation of automated valet parking technologies in parking lots,” Simul. Model. Pract. Theory, vol. 144, art. no. 103175, Nov. 2025, [Online]. Available: https://doi.org/10.1016/j.simpat.2025.103175.

[7] C. Zhao, F. Liao, X. Li, and Y. Du, “Macroscopic modeling and dynamic control of on-street cruising-for-parking of autonomous vehicles in a multi-region urban road network,” Transp. Res. Part C Emerg. Technol., vol. 128, art. no. 103176, Jul. 2021, [Online]. Available: https://doi.org/10.1016/j.trc.2021.103176.

[8] A. O. Elfaki, W. Messoudi, A. Bushnag, S. Abuzneid, and T. Alhmiedat, “A Smart Real-Time Parking Control and Monitoring System,” Sensors, vol. 23, no. 24, art. no. 9741, Dec. 2023, [Online]. Available: https://doi.org/10.3390/s23249741.

[9] T. Wang, S. Li, W. Li, Q. Yuan, J. Chen, and X. Tang, “A Short-Term Parking Demand Prediction Framework Integrating Overall and Internal Information,” Sustainability, vol. 15, no. 9, art. no. 7096, Jan. 2023, [Online]. Available: https://doi.org/10.3390/su15097096.

[10] M. Mikusova, J. Abdunazarov, and J. Zukowska, “Modelling of the Movement of Designed Vehicles on Parking Space for Designing Parking,” Commun. Comput. Inf. Sci., vol. 1049, pp. 188-201, Aug. 2019, [Online]. Available: https://doi.org/10.1007/978-3-030-27547-1_15.

[11] M. Mikusova and J. Abdunazarov, “Modelling of Vehicles Movements for the Design of Parking Spaces,” Lect. Notes Comput. Sci., vol. 11684, pp. 464-475, 2019, [Online]. Available: https://doi.org/10.1007/978-3-030-28374-2_40.